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The Relationship Between Urbanization and Eutrophication in Lake Dianchi Watershed in Kunming, China

By

Xiaoyu Yin

AN UNDERGRADUATE THESIS

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Thesis Advisor: Name: Dr. Daniel Snow

Thesis Reader: Name: Christine Haney/Dr. Megan Larsen

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TABLE OF CONTENTS:

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I would also like to acknowledge my indebtedness to my thesis readers Christine Haney and Dr. Megan Larsen, to Dave Gosselin and many others who have contributed their time, thoughts, skills and encouragement to this thesis.

Finally, I wish to devote this paper to my beloved families, who have given me love and encouragement, and have been supportive throughout my academic career.

Keywords:

China; Urbanization; Water; Eutrophication; Lake Dianchi; Land-use; Remote Sensing; Geographic information system (GIS); Human Activity; Agriculture;

1. Abstract

Due to the rapid economic growth in China, urban area in the City of Kunming has expanded overwhelmingly since 1970s along with dramatic population growth in Kunming. However, the source of drinking water that people of Kunming has depended on, Lake Dianchi, has been seriously polluted since 1990s. I looked at peer-reviewed literature and categorized them based on type of research method. After collecting and analyzing data from literature, the reverse relationship between urbanization and water quality in Lake Dianchi was concluded; the sources of phosphorus load to Lake Dianchi were mainly from human and agricultural activities.

2. Introduction

Eutrophication is defined as "the ecosystem's response to the enrichment of nutrients, mainly Phosphorus." (Hammer, 1973) With the increasing population and urban area, it is believed that eutrophication may be the result of urban expansion. This research studies the relationship between urbanization of the City of Kunming and eutrophication in Lake Dianchi in the southwestern part of Kunming, China. The types of land and how they are used is one of the factors that leads to pollution. The land use circumstance in the Lake Dianchi basin in the previous 30 years has significantly changed, in which the progressions of the arable area, construction- use land and other comparative changes are amazingly great, while the progressions of the water in the region and backwoods are not that self-evident. (Hong, 2011)

Moreover, the causes of eutrophication are also studied in this research. For example, the urban runoff and the change of urban and agricultural land use.

Nowadays, water issues are not a topic limited in specific area but all over the world. Many lakes and reservoirs in China have suffered severe eutrophication in recent decades. Especially in the city of Kunming, people concerned with the quality of Lake Dianchi. Not only the government and regulatory agencies, but also non-government organizations are devoting themselves to deal with issues in Lake Dianchi. Although both financial and human resources are constantly invested, the issues still exist.

Lake Dianchi has been very important for people in Kunming, it provides the industrial and agricultural water supply; it also has other purposes like water storage regulation, climate regulation, flood control, tourism and most significantly, the lake started providing drinking water for people in Kunming and in the basin since 1990. Unfortunately, due to rapid population growth and economic development, the livability of Kunming has changed significantly, so has the biodiversity in the lake.

Previous research done to date has focused on topics of phosphorus flow, land-use change and water quality in Lake Dianchi Watershed, however, there are only a few studies that investigate the correlation among them. In this research, I evaluated the role of urbanization, change of land-use and made connections between conclusions from literature.

3. Materials and Methods

Data I used in this research were adapted from the literature, government and regulatory websites and databases. There were ten peer-reviewed articles, two sources from government websites and eleven government official reports. I focused on analyzing and evaluating the data and conclusions from various sources and then concluded the relationship between urbanization, human activities and water quality. For all the sources, I categorized them into three different groups according to the type of research, which were Sampling sites; Phosphorus Flow and

Geographical Information System (GIS). As phosphorus is the dominant nutrient in a lake and plays an important role in the occurrence of eutrophication, studying the phosphorus content and flow is also necessary.

3.1 Sampling sites

Literature used sampling sites method mainly focused on evaluating water quality in Lake Dianchi. Some environmental research parameters used in literature of this category were Urban Expansion; Human Activities; Land Use; Turbidity; Nitrogen and Phosphorus Flow.

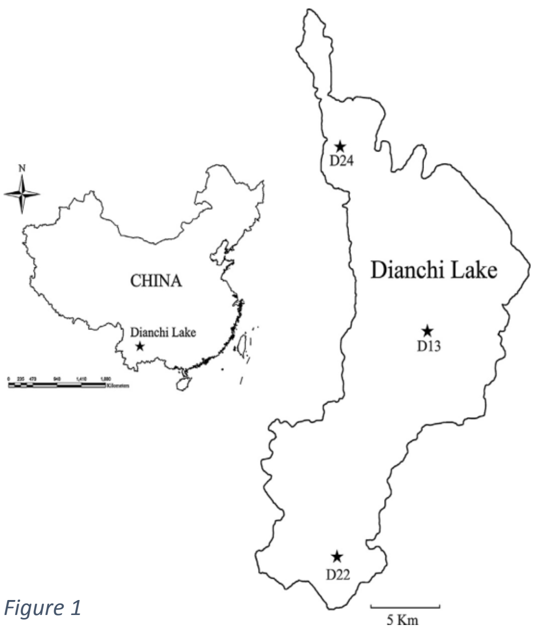


Figure 1

There were more than 150 sampling sites used in literature I reviewed, I selected three of them which I thought would be representative due to their locations - a northern site, middle site and a southern site. Those three sites were also used in the research from Wang's article. As shown in figure 1, three sites are marked across the lake. (D24 D13, D22) Water samples were collected and turbidity test was also conducted here in these three sites. (Wang, 2015) Three sites are reflecting the distance from the site to the urban area, so that the turbidity results from these sites could potentially reflect the impact of human activities on water quality with the relationship of distance.

3.2 Phosphorus Flows

Literature used phosphorus flow approach mainly focused on evaluating the source of phosphorus loading into Lake Dianchi including the analysis of surface runoff. The correlations of parameters such as temperature, time and total phosphorus were very useful in this research, where the observation of human activities and urbanization impact on eutrophication can be conducted.

Similar approach called Material flow analysis (MFA) was conducted by Liu and others determined the extraction, utilization, and discharge of phosphorus which directly led to eutrophication.

3.3 Geographical Information System (GIS)/Remote Sensing

This approach was used by many previous research focusing on analyzing changes in Land use and Land cover. In this research, I adopted a series of Landsat images, (took in year 1974, 1988, 1998, 2008) including Landsat Multispectral Scanner (MSS) images with a spatial resolution of 57-m taken in January of 1974, and Landsat Thematic Mapper (TM) images with a spatial resolution of 30-m taken in January of 1988 and April of 1998 and 2008. (Zhao, 2012) These images served as convenient and intuitive references for the observation of land use changes.

3.4 DPSIR Assessment (Wang, S, et al., 2015)

Driving force, Pressure, Status, Impact and Risk (DPSIR) assessment is a model used to overcome the disadvantages of data selection. It also identifies if any bias exists in the method section using an ecological approach and an environmental sustainable development criteria. In this research, due to the literature-skewed approach, there is not too much field data, so that an assessment of data selection is important and it could improve the research process by increasing data accuracy. This assessment also gives a comprehensive report on analysis of water quality.

By reviewing all the research materials including water quality, land use change and phosphorus load in Lake Dianchi watershed, I concluded the correlation between urban expansion and water quality in Lake Dianchi along with the analysis of phosphorus flows in Lake Dianchi Watershed.

4. Result of Assessment

Standard of Comprehensive Pollution Index Classification is used by China's regulatory agencies; and the Water Quality Classification is classified into six categories from I to Poor V, corresponding to Cleanness to Seriously polluted.

Table 1

Standard of Comprehensive pollution index classification						
Pollution Index	≤0.2	0.2-0.40	0.40-0.70	0.70-1.0	1.0-2.0	>2.0
Water Quality Classification	I	II	III	IV	V	Poor V
Pollution Level	cleanness	Sub-cleanness	Slightly polluted	Medium polluted	Heavily polluted	Seriously polluted

According to the annual report from the Office of Dianchi Pollution Comprehensive Management Coordination Leading Group (ODPCMCLG), the reported annual Water Quality Classification for the three sampling sites from 1970-2011 are:

Table 2

Year	1970-1990	1990-2000	2000-2003	2004	2005	2006	2007	2008	2009	2010	2011
Water Quality Classification	III	IV	V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V

Unfortunately, due to the lack of systematic recording, reports from 1970-1990 and 1990-2000 are based on average Water Quality Classification. (ODPCMCLG No. 2011613, 2011) Generally, the Water Quality Classification trend is clear that the water quality in Lake Dianchi deteriorated dramatically since 1990. 1990 was also the year when China's economy started growing rapidly.

The Geographic Information System was used by Zhao and others to conduct a series of images showing the Land-use changes from 1974 to 2008 in Lake Dianchi Basin. The developed area increased dramatically throughout the 40-year period.

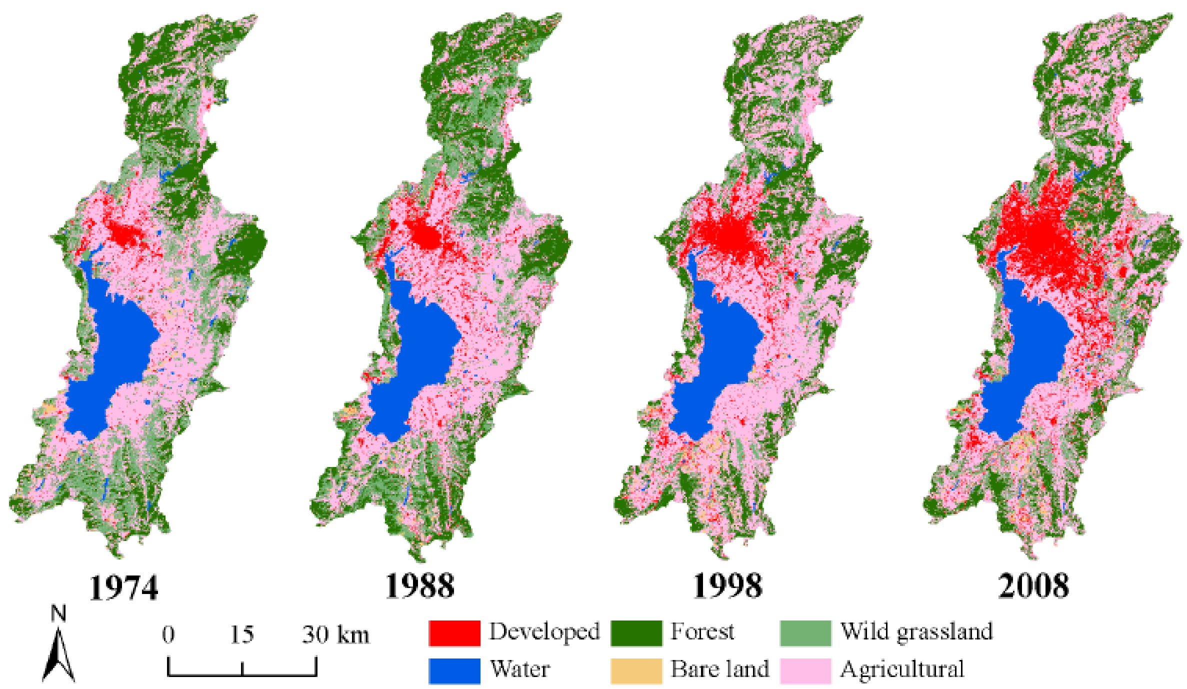
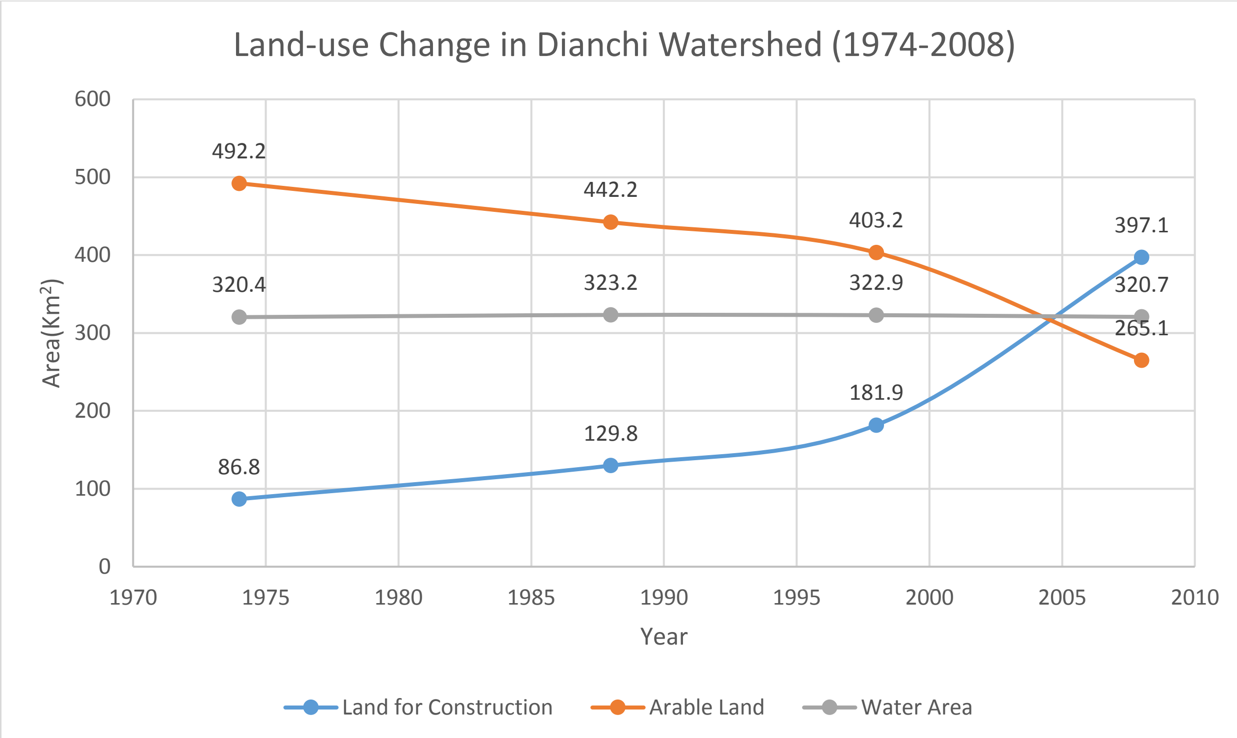


Figure 2



Data from Hong, Z., Hailin, L., & Zhen, C. (2011)

Figure 3

With the comparison of worsened water quality and increased land for construction in the same period from 1974-2008, a relationship has been determined – urbanization has an inverse relationship with water quality in Lake Dianchi Watershed.

Per the phosphorus flow research, natural water runoff and urban wastewater discharge contribute phosphorus into Lake Dianchi, which are considered as Non-Point Source pollutants.

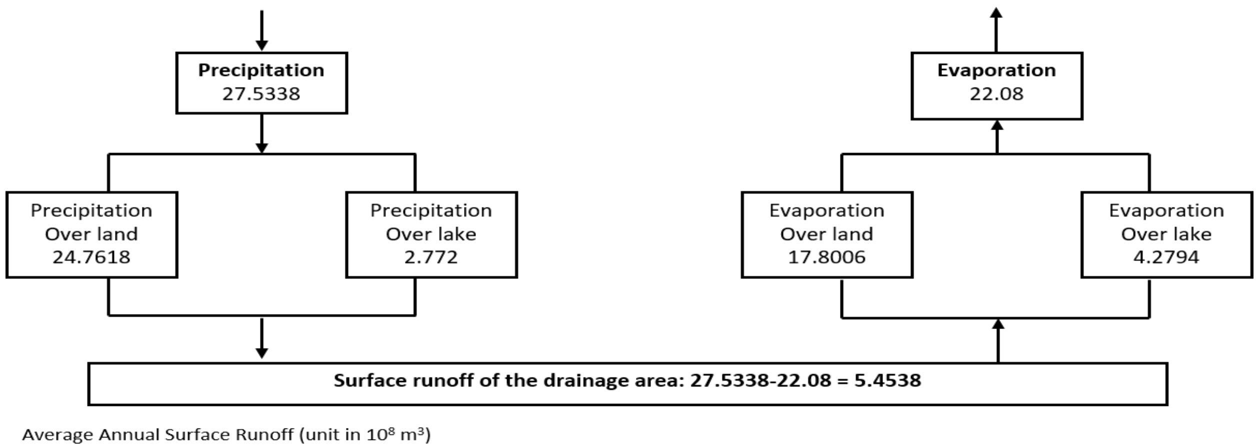
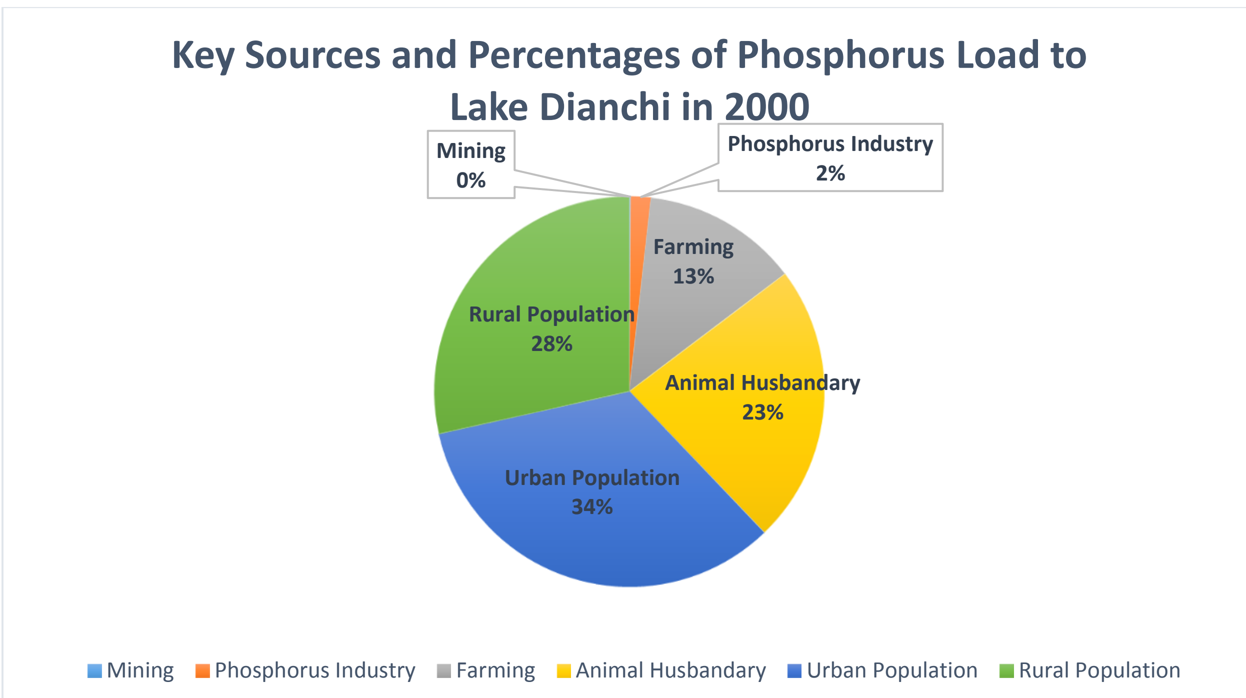


Figure 4



Data from Liu, Y., Chen, J., & Mol, A. (2004)

Figure 5

There are also many phosphorus mines, factories, and sewage treatment plants located in the Dianchi drainage basin. These Point Source pollution are easier to be controlled, however, due to the need of economic development, ignoring policies and restrictions are common among industries.

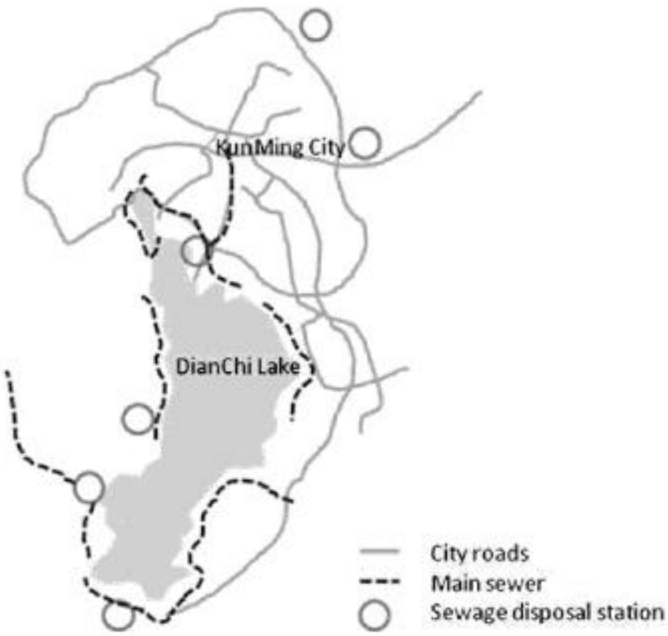


Figure 6

5. Discussion

Throughout four decades' development since 1974 in the Dianchi watershed, the pattern shows that there are ongoing changes in land-use and land-cover in the perspectives of structure, shape and distribution. It is classified into six categories of land, which are agricultural land, forest land, wild grassland, bare land, developed area and water. Agricultural land made up forty percent of the total land area of the watershed, which implies how important role that agriculture plays in Dianchi watershed socioeconomically. Despite the importance of agriculture in this area, the developed area showed the greatest change in the past forty years - economic development was prominent, while environmental protection was hardly executed. In other words, economic growth occurred at the expense of environmental quality and sustainability.

Agriculture lands are also very sensitive to the magnitude of rainfall where rainfall is the key point in determining runoff and nutrients loading, and in urban areas, this rainfall-nutrient loading relationship is weakened since there is the little attention to phosphorus flow. (Sorannon, et al., 1996)

Not only the defective development strategy, but the lack of awareness also exists. The insufficient awareness of scientific data gathering and monitoring programs, made it harder to establish lake protection strategies and goals. Although the efforts slowed down the tendency to continuous deterioration with the ninth Five-Year Plan for Water Pollution Control that established by the regulatory agency every five years, the hyper-eutrophication of the lake and the related ecological devastation has not yet been substantially reversed. (Jin, et al., 2006)

The lack of awareness of the ecological fragility on Lake Dianchi also had the most significant impacts on water quality. People are not well-educated that Lake Dianchi is so fragile that the expansion of urban area and growth of population and industry in the drainage basin would harm the lake greatly. Overfishing and introduction of exotic fish and species are other examples. The lake system has become more a man-made regulated reservoir rather than a natural lake. The loss of wetlands along the shoreline, due to economic and industrial development, have caused the loss of the lake's natural barrier. (Jin, et al., 2006)

During this research, it has also been found that acquiring scientific data was very hard as there was a few available data on Lake Dianchi. Most data are from 1950-2000, focusing on lake biology like fish and plankton, which are not current and up-to-date; data regarding water quality and ecology are inadequate too. It is unfortunate because many current feasible protection plans depend on historic perspectives. Despite the lack of research and data, the lack of sharing the information among agencies, institutes, and individuals is another problem.

6. Alternative Solution

The idea of "water replacement" has been purposed by the government in 2013. It is a project that extracts polluted water in Lake Dianchi little by little and restores clean water back into Lake DIanchi by building dams in the upper stream area in Northeastern Kunming. Clean water is either by treatment or from other water bodies nearby. Ideally, there will be 566 million m^3 of clean water (Water Quality Classification III) restored every year. (Three-year, 2013) Although the "water replacement" project seems feasible, it requires huge investment and time. Simultaneously, control of surface runoff in urban areas is still necessary.

7. Conclusion

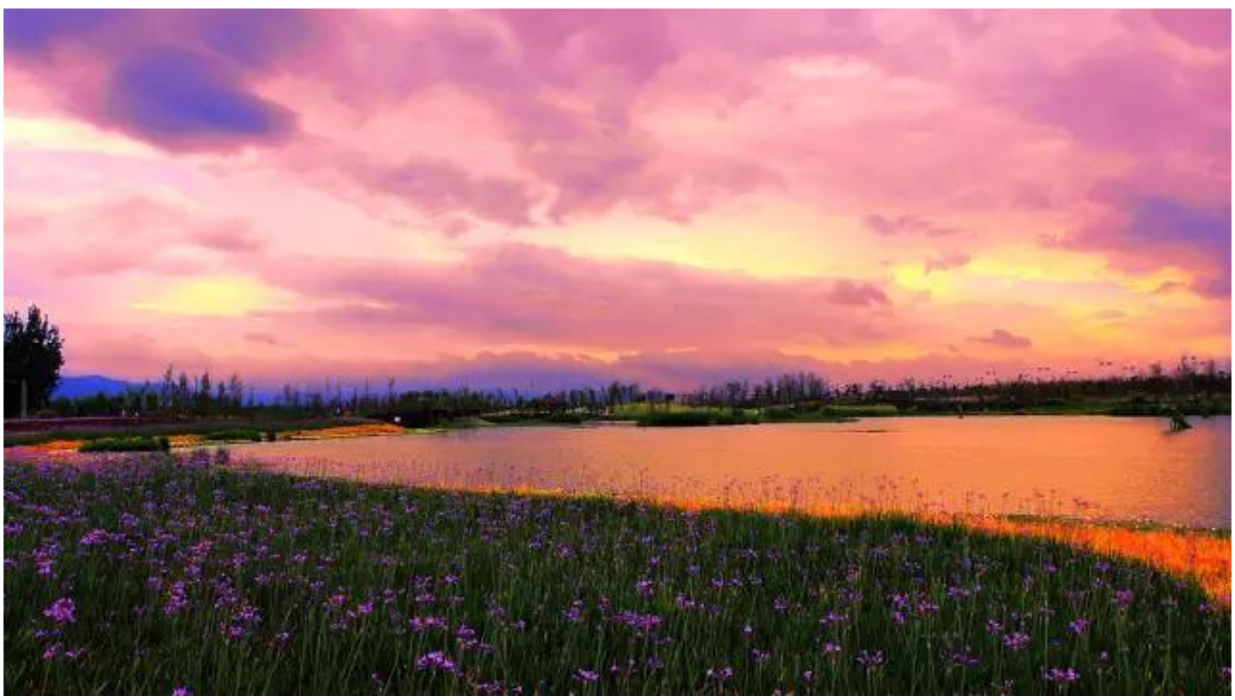
Throughout the research and analysis, the evaluation with Water Quality, Land-use change and Phosphorus Flow, successfully concluded that urbanization has negative impacts on water quality in Lake Dianchi in Kunming, China. According to the analysis of Phosphorus Load, the key sources are lied in agricultural and urban activities; to better control and improve the water quality in Lake Dianchi, the control of wastewater and the implementation of restoration projects are imperative. Here are some recommendations that would help for future research and projects.

First of all, more scientific research should be conducted; data and information should be shared no matter when people acquire them.

Secondly, the farmland along the lake's shoreline has been defined as the "fundamental farmland" that should be protected. Returning the farmland to the lake body for lake shoreline ecological restoration is necessary. Restrictions on the rights to approve and manage phosphorus mining are needed, and efforts should be made to recover vegetation on mining sites.

Finally, better management of surface runoff, advanced wastewater treatment and the reuse of treated wastewater are necessary.

Starting in 2015, there are wetland restoration projects going on around the lake, for example, the Wujiatang Wetland Park and Haidong Wetland Park as in the images below. It is believed that Lake Dianchi will shine again in the near future.



Images from http://en.yunnantourism.com/content.aspx?id=018613619932

Tables

Table 3

Standard of Comprehensive pollution index classification						
Pollution Index	≤0.2	0.2-0.40	0.40-0.70	0.70-1.0	1.0-2.0	>2.0
Water Quality Classification	I	II	III	IV	V	Poor V
Pollution Level	cleanness	Sub-cleanness	Slightly polluted	Medium polluted	Heavily polluted	Seriously polluted

(ODPCMCLG No. 2011613, 2011)

Table 4

Year	1970-1990	1990-2000	2000-2003	2004	2005	2006	2007	2008	2009	2010	2011
Water Quality Classification	III	IV	V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V

(ODPCMCLG No. 2011613, 2011)

Figures

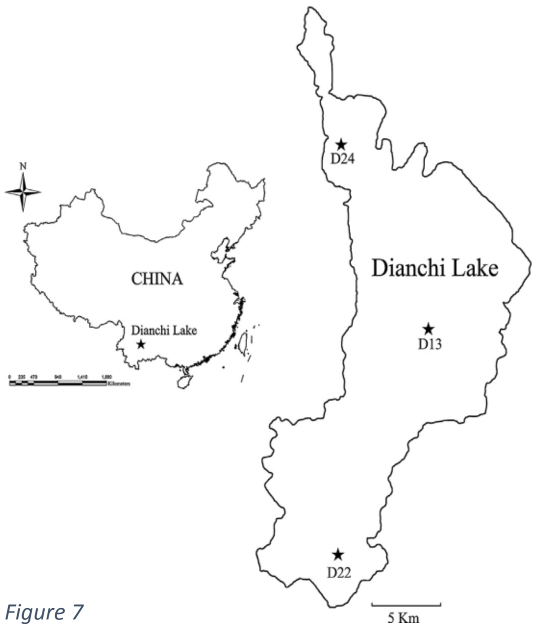


Figure 7

Wang, Z., Zhou, J., Loaiciga, H., Guo, H., & Hong, S. (2015).

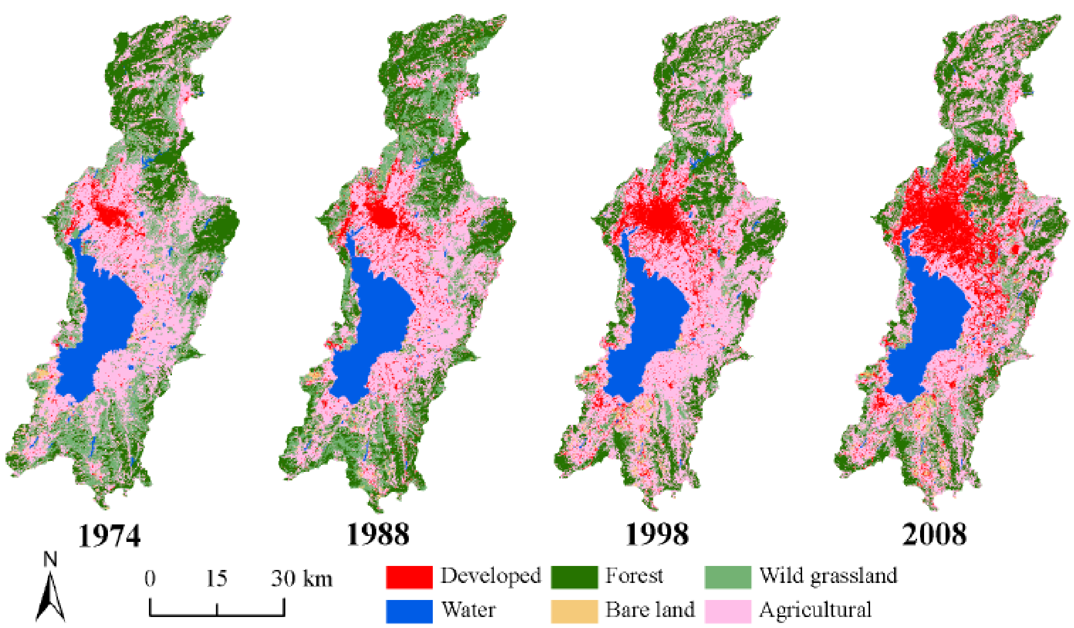


Figure 8

Hong, Z., Hailin, L., & Zhen, C. (2011)

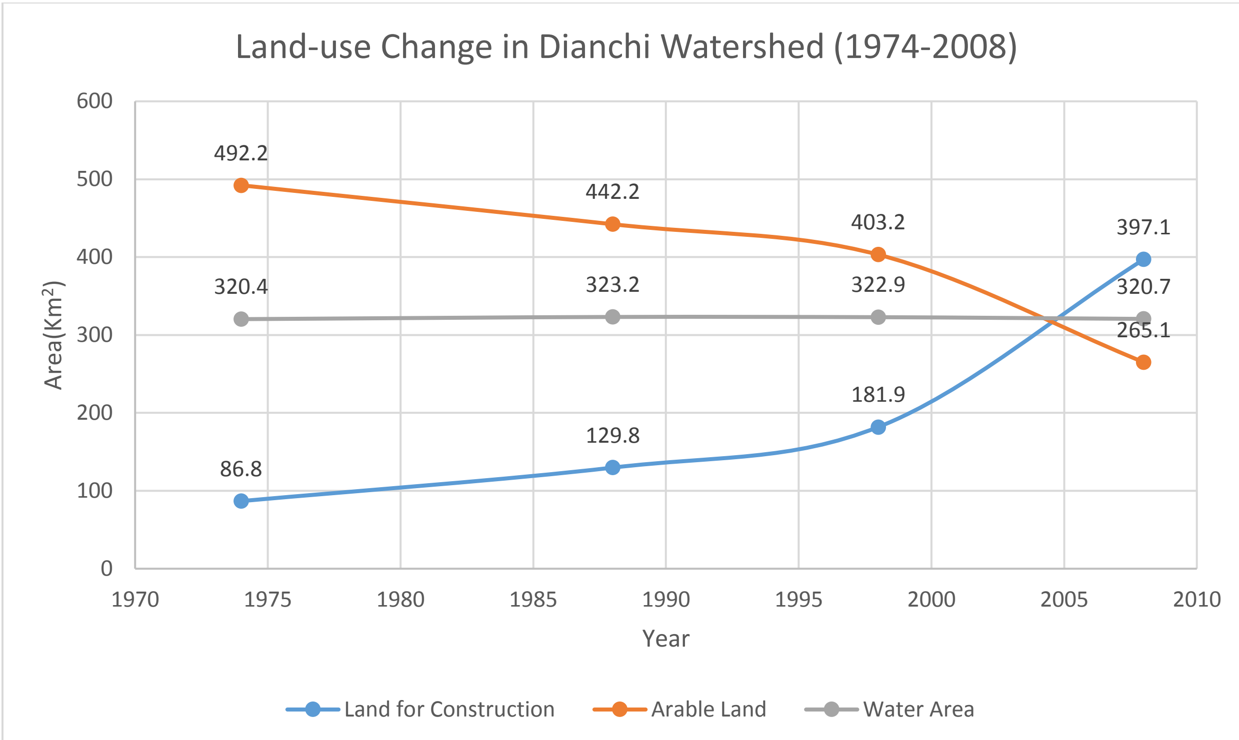
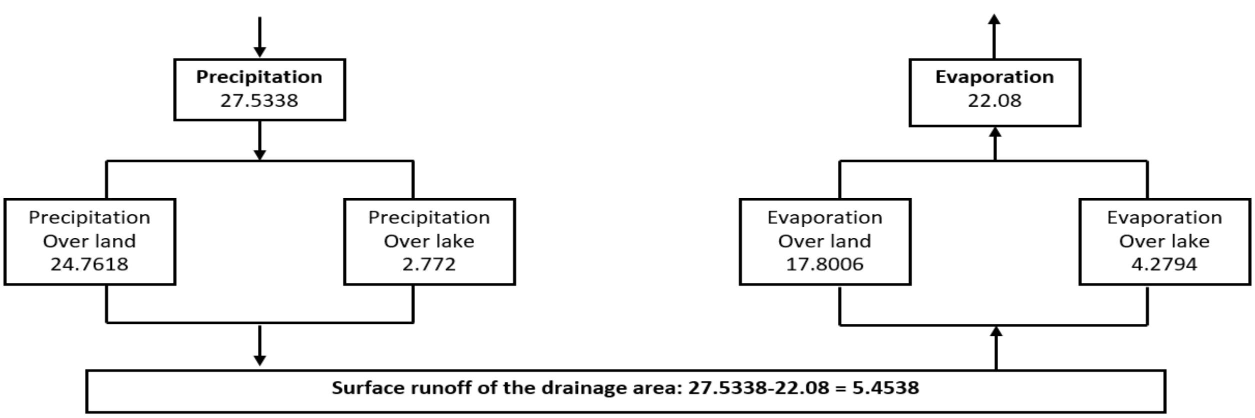


Figure 9

Data from Hong, Z., Hailin, L., & Zhen, C. (2011)



Average Annual Surface Runoff (unit in 10^8 m^3)

Figure 4

Jin, X., Wang, L., & He, L. (2006)

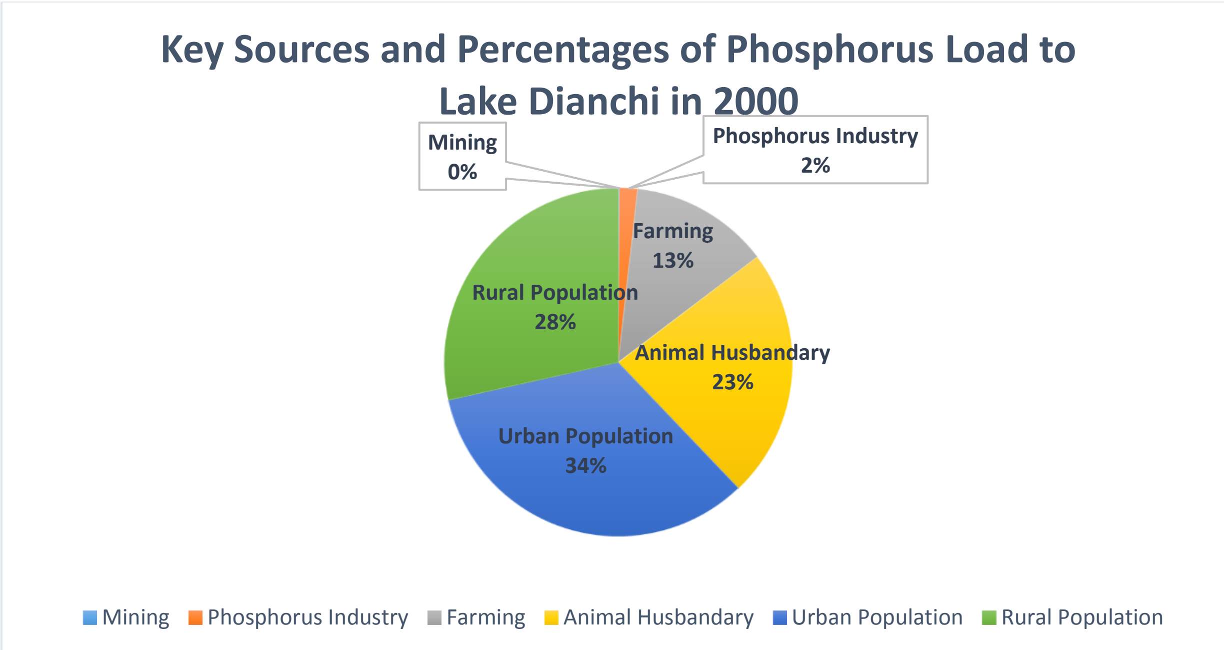


Figure 10

Data from Liu, Y., Chen, J., & Mol, A. (2004)

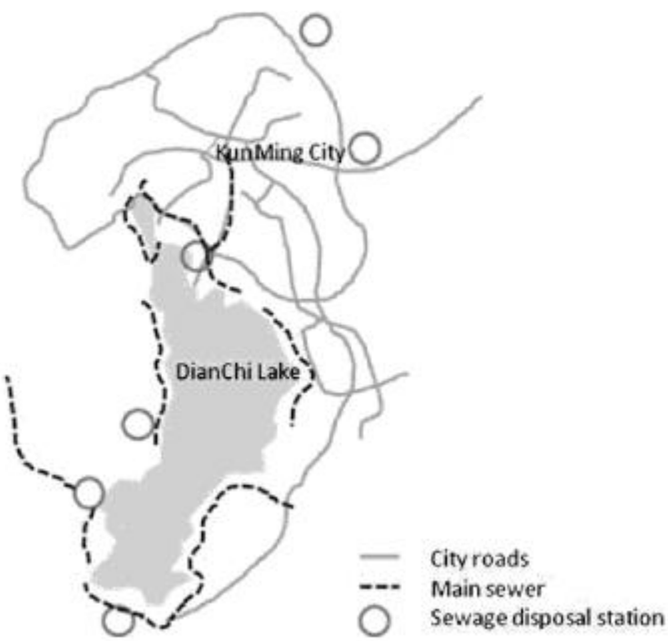


Figure 11

Liu, Y., Chen, J., & Mol, A. (2004)

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Appendix A: Data Sources

Land-use Change: Hong, Z., Hailin, L., & Zhen, C. (2011).

Land type	1974		1988		1998		2008	
	Area (km^2)	Occupation (%)	Area (km^2)	Occupation (%)	Area (km^2)	Occupation (%)	Area (km^2)	Occupation (%)
Arable land	492.2	17.3	442.2	15.6	403.2	14.2	265.1	9.3
Land for construction	86.8	3.1	129.8	4.6	181.9	6.4	397.1	14.0
Woodland	1272.3	44.8	1256.7	44.2	1252.6	44.1	1252.8	44.1
Water area	320.4	11.3	323.2	11.4	322.9	11.4	320.7	11.3
Other types	669.0	23.6	688.7	24.2	680.1	23.9	605.0	21.3

Phosphorus Load: Liu, Y., Chen, J., & Mol, A. (2004).

Source	Phosphorus Load (tons)	Percentage
Mining	2.0	0.1
P-industry	28.0	1.7
Agriculture		
Farming	218.6	12.9
Husbandry	392.3	23.2
Human		
Urban Population	569.6	33.6
Rural Population	482.5	28.5
Sum	1693.0	100

H.R. Rep. No. 2011613 at 1 (2011). Dianchi Pollution Comprehensive Management Coordination Leading Group Office

Standard of Comprehensive pollution index classification						
Pollution Index	≤0.2	0.2-0.40	0.40-0.70	0.70-1.0	1.0-2.0	>2.0
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Year	1970-1990	1990-2000	2000-2003	2004	2005	2006	2007	2008	2009	2010	2011
Water Quality Classification	III	IV	V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V	Poor V